

**A MARK-RECAPTURE EXPERIMENT TO ESTIMATE THE ABUNDANCE OF
KUSKOKWIM RIVER COHO SALMON, 2001**

By

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and

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ABSTRACT

Abundance estimates of Kuskokwim River coho salmon were made in 2001 between Kalskag (approximately 309 river km (rkm) and Birch Tree Crossing (rkm 341), and between tagging sites and four weired tributaries. Fish wheels and drift gillnets were used to capture fish for tagging. Coho salmon were tagged with uniquely numbered spaghetti tags and two secondary marks were used to assess tag loss. The total number of tags deployed was 3,027 of which 1,291 were deployed at Kalskag and 1,736 at Birch Tree Crossing. Thirteen of the fish tagged at Kalskag were recovered at Birch Tree Crossing. At the weir sites, 233 tags were observed. Of the tagged fish recovered at the Kogrukluk and George River weirs, fish tagged on or before August 17 had a significantly slower swimming speed (18.9 and 9.4 km/day) than fish tagged after that date (27.5 and 15.4 km/day). There was no correlation between live box holding time or the number of fish held and fish speed or rate of recapture. However the rate of recapture was positively correlated with the length distribution of tagged fish and coho salmon capture at weirs. Significant differences were detected between coho salmon tagged from fish wheels and captured in the lower, middle, and upper basin weirs, but there was no significant difference for coho salmon tagged from drift gillnets and middle and upper basin weir sites. The abundance estimate was 162,528 (CV = 0.256) between Kalskag and Birch Tree Crossing. Between the tagging sites and middle basin weir sites the estimate was 374,139 (CV = 0.069), and upper basin weir sites the estimate was 975,644 (CV = 0.199). The difference in abundance estimates is primarily because of differences in tagging ratios at the various recovery sites. These differences may be caused by 1) handling induced survivability of the tagged fish, 2) unequal probability of capture at the marking site between the various spawning populations represented at the recapture sites, and 3) incomplete mixing of tagged and untagged fish.

KEY WORDS: Kuskokwim River, coho salmon, mark-recapture, abundance estimate, Kalskag, Kogrukluk, George River, tagging ratio

INTRODUCTION

The Kuskokwim River is the second largest river in Alaska and drains a basin of about 130,000 km² along its 1,340-km course from interior Alaska to the Bering Sea (Figure 1) (Brown 1983). This Western Alaskan drainage produces five anadromous species of Pacific salmon and supports one of the most important subsistence fisheries in the state. Coho salmon (*Oncorhynchus kisutch*) produced by this system is considered one of the largest coho salmon runs into single river drainage in Alaska.

Coho salmon is the most important commercial fishery species on the Kuskokwim River (Burkey et al. 2001). From 1991-2000, the average commercial harvest was 453,755, and ranged from 23,593 in 1999 to 937,299 in 1996 (Burkey et al. 2001). The 2001 commercial harvest was 192,998. The subsistence harvest during this period averaged 33,699 and ranged from 24,864 in 1998 to 50,331 in 1991. The subsistence coho salmon harvest in 2001 was 29,504.

A fisheries disaster was declared in Bristol Bay and the Kuskokwim and Yukon River by the State of Alaska in 1997 and 1998. In response, the United States Congress appropriated \$7.0 million in the Western Alaska Salmon Fisheries Disaster Mitigation Research Plan (WASFDP) for development of research to prevent future disasters (Eggers 1999). This plan recognizes that the health of western Alaska salmon is critically important for residents of the region. The WASFDP allocated \$495,000 to the Alaska Department of Fish and Game (ADF&G) to conduct a mark-recapture study on Kuskokwim River coho salmon. The primary objective of this project was to estimate total run size of coho salmon in the Kuskokwim River upstream of Kalskag, which is located at 309 rkm upstream from the mouth of the river. A secondary objective was to investigate the run timing past Kalskag of various spawning population aggregates monitored at the weir projects.

METHODS

A mark-recapture study was staged near Kalskag and Aniak (Figure 2). This section of the river was selected because: (1) the sites were located approximately 300 river kilometers (rkm) upstream from the mouth of the Kuskokwim River, and thus fish should be physiologically adjusted to living in freshwater and more tolerant of capture and tagging stresses; (2) the sites were located above Bethel, where approximately one-third of the fish are harvested, and thus harvest of tagged fish should be reduced; (3) the sites are below most coho salmon spawning streams; and (4) the water current at the sites were adequate for the fish wheel operation used to capture the coho salmon.

This study was designed to have two mark-recapture events. The first event compared tag recoveries between Kalskag (309 rkm) and Birch Tree Crossing (341 rkm). The second event compared tag recoveries between the Kalskag/Birch Tree Crossing area and weirs used for salmon escapement monitoring on the George, Kogruklu, Tatlawiksuk and Takotna Rivers. Fish

wheels and drift gillnets were used for capturing coho salmon at Kalskag from July 22 through September 8, and at Birch Tree Crossing from July 22 to September 10. Birch Tree Crossing served both as a tag recovery site for fish tagged at Kalskag, and as a tagging site for fish that would be recovered at the weirs.

Capture Methods

Fish Wheels

Four fish wheels were used; one pair was anchored near Kalskag and a second pair near Birch Tree Crossing. The fish wheels were positioned so that the members of each pair were on opposite sides of the river. Each fish wheel consisted of 2-baskets measuring 2.5×2.5 m (length, width) made of spruce poles, a live box measuring $2.4 \times 1.2 \times 0.06$ m (length, width, depth) made of plywood perforated with holes attached to the offshore side of each fish wheel, and a weir (length ~ 5 m) positioned perpendicular to the bank along the onshore side of each fish wheel.

Fish wheels were operated continuously, except for periods of maintenance, adjustment, and relocation. Two 2-person crews worked each pair of fish wheels. Each crew worked one 8-hour shift each day. Initially, the two shifts were from 0400 to 1200 hours and from 1600 to 0000 hours, but as the season progressed and daylight hours shortened the schedule was progressively adjusted until at the end of the season the two shifts were from 0600 to 1400 hours and 1500 to 2300 hours. On average, the fish wheels were checked every 3.4 hours

Drift Gillnets

In addition to the fish wheels, drift gillnets were used to augment the capture coho salmon from August 8 through September 5 when high water levels reduced the efficiency of fish wheels. Two mesh sizes were used, 4-in (10.16 cm) and 6.5-in (16.51 cm), and the gillnets measured 45 meshes deep and were either 15 fathoms (27.43 m) or 25 fathoms (45.72 m) in length. The net length that the crew fished on a give day was based on catch rates; for example, the crew used the 15-fathom gillnet when catch rates were high. The crew deployed gillnets from an 18-ft (5.5 m) skiff, and immediately began retrieving the net at the first sign that a fish was entangled. Any species of fish caught other than coho salmon (i.e., bycatch) were immediately released. Coho salmon, however, were first freed from the net then lifted into the skiff where they were placed into a tub of fresh river water, tagged and released. When too many coho salmon were caught, excess fish were immediately released without tagging.

Tagging

Tagging consisted of one primary and two secondary marks. The primary mark was a 36-cm spaghetti tag. To increase tag strength, each tag was reinforced with jeweler wire. Printed on

each tag were a unique identification number and the phone number of the ADF&G Anchorage office. Three tag colors were used to distinguish the tagging site and gear type used for capture. Fluorescent pink tags were used for fish caught by fish wheels in Kalskag, green tags for fish caught by the fish wheel in Birch Tree Crossing, and white tags for fish caught with drift gillnets in both sites.

Two types of secondary marks were used to assess tag loss. The adipose fin was marked with a hole-punch, an axillary fin clipped to identify the tagging site. The left axillary fin was clipped at Kalskag, and the right axillary fin was clipped at Birch Tree Crossing.

The coho salmon selected for tagging were placed in a plywood cradle filled with river water. The following data were recorded for each coho salmon: mid-eye-to-fork (MEF) length measured to the nearest 5 mm, sex (determined from external characteristics), injuries (snout damage, split fins, net marks, lamprey wounds, and seal bites), and skin color (bright silver, silver-pink, dark-pink, dark red). The spaghetti tags were sewn through the back of healthy coho salmon just below the dorsal fin and about four rays up from the posterior side of the dorsal fin, the tag was secured by crimping both ends of the spaghetti tag together in a brass sleeve. A paper punch was used to put a hole in the adipose fin, and a dog-toenail clipper was used to clip the axillary fin. Unhealthy coho salmon were released without a tag. Bycatch fish were identified, counted, and released.

Tag Recovery

Six weir projects were used as tag recovery sites (Figure 1), two of the weirs were located downstream of the tagging site, and four were located upstream. The downstream weirs (lower basin) were on the Kwethluk and Tuluksak Rivers. The upstream weirs were located on the George and Kogrukluk Rivers (middle basin), Tatlawiksuk and Takotna Rivers (upper basin).

Whenever possible, weir crews captured tagged fish as the fish passed upstream through the weir, and recorded the date and tag number; these fish are described as “recovered” tags. The crews, however, were not able to capture all tagged fish that passed through the weirs. Even when the fish could not be captured, the crew was able to identify the tag color, which was recorded with the date. The sum of all tagged fish that passed through the weir, whether the tag was recovered or not, are described as “observed” tags. The weir crews also inspected untagged fish for the presence of secondary marks as a means to assess the incidence of tag loss, these fish are described as “inspected”. Ideally fish sampled for tag loss should be unbiased, however this first year of operation crew were not fully aware of how to draw an unbiased sample and therefore tag loss analysis is limited.

Tagged fish were also caught by subsistence, commercial and sport fishers. These fishers were encouraged to return the tags through a tag lottery. The lottery was advertised with posters, radio announcements, and public meetings.

Data Analysis

The following assumptions for this mark-recapture study were tested:

- 1) marking and handling will not affect the catchability of the fish, and
- 2) all marked fish will mix completely with unmarked fish between sampling events.

To test the first assumption, the effect of holding density, and holding time in live boxes, on the recapture rate of the tagged fish. Holding density was calculated as a product of hours the fish were held in the live box and the number of fish in the live box. Chi-square analysis was used to examine difference in recapture rate and travel speeds among various holding density groups.

To examine the effect of holding time on the recapture probability based on fish length, logistic regression was constructed in which recapture-no recapture of tagged fish was regressed with length and holding time, which were delineated into four holding groups (< 1, 2, 3-5, >5 hours).

To examine the second assumption, equality of tagged-untagged ratio was examined among various weir tag recovery sites using chi-square analysis.

Abundance Estimate

A modification of the Chapman estimator (Seber 1982) was used to estimate total coho salmon run size:

$$\hat{N} = \frac{(C+1)(M+1)}{R+1} - 1 \quad (1)$$

$$V[\hat{N}] = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \quad (2)$$

where:

\hat{N} = estimated abundance of coho salmon in the Kuskokwim River upstream from Kalskag, or upstream from the Kalskag-Birch Tree Crossing region,

M = the number of coho salmon tagged at Kalskag alone, or at Kalskag and Birch Tree Crossing pooled

C = the number of coho salmon examined at Birch Tree Crossing, or counted past the four weirs; and,

R = the number of tagged coho salmon recovered at Birch Tree Crossing or moving past the four weirs.

RESULTS

Tag Deployment

A total of 3,027 coho salmon were tagged between July 22 and September 10 using a combination of fish wheels and drift gillnets; 1,291 fish were tagged at Kalskag and 1,736 at Birch Tree Crossing (Table 1). The catch per unit effort (CPUE) was variable throughout the season. Fish wheels positioned along the right bank at both Kalskag and Birch Tree Crossing had peak CPUEs in early August (Figure 3). The CPUE for fish wheels positioned along the left bank had no distinct peak (Figure 4). Comparing the number of catches between right and left bank, more coho salmon were captured in right bank wheels (897 Kalskag; 1,334 Birch Tree) than in left bank wheels (205 Kalskag; 340 Birch Tree Crossing; Table 2).

Drift gillnets were used to capture coho salmon from August 11 through September 5 when fish wheel catches declined (Table 1, Figure 5). During this time, water levels also increased. The Birch Tree Crossing site had higher drift gillnet CPUE's than the Kalskag site. Peak drift gillnets CPUEs occurred in mid-August at both Kalskag and Birch Tree Crossing.

Tag Recovery

Tagging Sites

Thirteen tagged coho salmon were recaptured at Kalskag; nine of these fish were originally tagged from Kalskag and four from Birch Tree (Table 1). At Birch Tree Crossing, 25-tagged coho salmon were recaptured, 13 originating from Kalskag and 12 from Birch Tree. Of all the coho salmon recaptured, 39% were captured on the opposite bank from where they were tagged. Traveling time between Kalskag and Birch Tree Crossing ranged from 1 to 5 days ($n = 13$) for fish tagged at Kalskag and recaptured at Birch Tree Crossing; and from 0 to 4 days ($n = 3$) for fish tagged at Birch Tree Crossing and recovered at Kalskag. For coho salmon recaptured at the same location that the individuals were tagged, the number of days between tagging and recapture ranged from 0 to 3 days ($n = 8$) at Kalskag and from 0 to 6 days ($n = 13$) at Birch Tree Crossing.

Weir Sites

A total of 233-tagged coho salmon were recaptured at various weir sites (Table 3), of which 19 were reported downstream of the tagging sites, and 214 were reported upstream of the tagging sites.

Voluntary Tag Recoveries

A total of 169 tags were returned from subsistence, commercial and sports fisheries (Table 4), of which 89 were captured downstream, 58 were captured upstream, and 18 were captured near the tagging sites. The capture location was unknown for four of the tags returned.

Travel Speed

Tag recoveries at the weir sites allowed determination of the travel speed between the tagging site and weirs for individual fish. Overall, fish traveled faster as the season progressed, so results are described in terms of early season (fish tagged before 18 August) and late season (fish tagged on 18 August or later). The mean travel speed for tagged fish recovered at the Kogruklu River weir was 18.9 km/day for fish tagged early in the season and 27.5 km/day for late season, which was a statistically significant difference (t-test: $t = 10.13$, $df = 90$, $P < 0.001$; Table 5; Figure 6-7). The mean travel speed for tagged fish recovered at the George River weir was 9.4 km/day for early season and 15.4 km/day for late season, which was again a statistically significant difference (t-test: $t = 4.45$, $df = 33$, $P < 0.001$; Table 5; Figure 6-7). Only late season fish were recovered at the upper basin weir sites. The mean travel speed for fish recovered at the Tatlawiksuk River weir was 25.8 km/day (Table 5; Figure 6-7). One fish was recovered at the Takotna River weir. Its travel speed was 33.8 km/day (Table 5; Figure 6-7). The mean travel speed calculated for tags returned by subsistence, commercial and sport fishers show similar trends similar to what was found at the Kogruklu and George River weirs (Table 5).

Abundance Estimate Diagnostics

Effects of Holding Time and Length

Recapture rates ranged from 0.049 to 0.056 among four holding groups (<1, 2, 3-4, >5 hours), which was not significantly different (Chi-square test: Chi-square = 0.865, $df = 3$, $P = 0.834$) (Figure 8). Also, no correlation was found between travel speed and holding density ($R^2 = 0.000297$; $n = 299$; $P = 0.797$).

The range of fish lengths for coho salmon captured at the weir sites was generally larger than that of tagged fish. The length of fish sampled at the various weirs as part of the normal age-sex-length sampling ranged from 410 to 670 mm ($n = 2,393$; Table 6). The sub-group of tagged fish that was recovered at the weirs ($n = 152$) ranged in length from 510 to 650 mm, and the length of tagged coho salmon ranged from 345 to 675 mm ($n = 2,979$).

No significant difference was detected in length distributions of the tagged population and the tagged fish recovered at the weirs (two-sample Kolmogorov-Smirnov test detected $P = 0.065$), however a significant difference existed between the length distribution of the tagged population and the lengths of coho salmon sampled at the weirs as part of the normal age-sex-length

sampling (KS test: $P < 0.0001$). Logistic regression showed the rate of recapture was positively correlated with fish length, but not correlated with holding time (Table 7).

Tag Recovery

The overall ratio of tagged to untagged coho salmon at the weirs ranged from 0.0004 to 0.008 (Table 3). The tag ratios were not significantly different between the weirs in each river basin, (Lower basin: Chi-square=3.697, df=1, $P = 0.054$; Middle basin: Chi-square=0.319, df=1, $P = 0.572$; Upper basin: Chi-square=0.012, df=1, $P = 0.912$). However, a significant difference was detected among the three basins. The ratio was the lowest in the lower basin and highest in the middle basin (Chi-square=195.25, df=2, $P < 0.001$). This difference was largely attributed to fish wheels; when the tag ratio was calculated separately for fish wheels and drifts, no significant difference was found between middle basin and upper basin for drifts (Chi-square= 0.0216, df=1, $P = 0.883$), whereas a significant difference was found for fish wheels (Chi-square= 177.591, df=1, $P = 0.001$).

Tag Loss

Three of the 92 untagged fish inspected for secondary marks had hole-punched adipose fins. One of the three untagged coho salmon was found in the Tatlawiksuk River weir, and the fish had a clipped left axillary fin indicating it was tagged at Kalskag. The other two fish reported as untagged, were found at the Kogrukluk River weir; these fish actually did have a tag inserted in their bodies, but the numbers on the tags were unreadable.

Abundance Estimate

Abundance estimates were made: 1) between Kalskag and Birch Tree Crossing, and 2) between tagging sites and middle and upper basin weir sites. Tags recovered in the lower basin were subtracted from the pool of total tags deployed. The effect of tag loss was considered insignificant, so was not incorporated into the analysis. Separate abundance estimates were made for each of these data sets, because the difference between the tag ratio in middle basin and upper basin weirs was significant. Separate abundance estimates were also made using the fish wheel and drifts data sets. The final abundance estimate upstream of Kalskag was made using the drift data set, because the tag ratio was similar between middle and upper basin data sets

Estimates of the total coho salmon abundance upstream of Kalskag were made using six separate data sets. Based on the Birch Tree Crossing data set, the estimate was 162,528 fish (CV = 0.256; Table 8). Between the combined Kalskag-Birch Tree Crossing tagging site and the middle and upper basin weir sites, the abundance was estimated to be 374,139 coho salmon (CV = 0.069), and using only the upper basin data set the estimate was 975,644 coho salmon (CV = 0.199; Table 9). Considering only the drift gillnet data set, abundance estimate was 447,604

(CV=0.211; Table 10). For fish wheels the estimate was 367,502 (CV=0.072) for the middle basin and 1,072,139 (CV=0.217) for the upper basin (Table 11).

DISCUSSION

The wide difference in abundance estimates is primarily caused by differences in the tagging ratio, which indicates: 1) the handling of the fish somehow affected survivability of the tagged coho salmon, 2) the fish wheels and drift gillnets did not capture representative sample of coho salmon, 3) tagged fish did not mixed completely with untagged fish.

The argument that handling would increase mortality of tagged fish is widely circulated throughout the literature. For instance, Carlon (2000) found a decrease in the mortality of radio tagged coho salmon by relocating their fish wheel sites upstream, by modifying fish wheel handling techniques, and by reducing holding time in live boxes. Holding time in fish wheel live boxes has been implicated to delayed mortality in fall chum salmon on the Yukon River (Underwood et al. 2002). Although this delay is consistent with a decrease of the tag ratio from middle to upper basin weirs (i.e. delayed mortality of tagged fish), we believe that fish handling had little effect on the mortality of tagged coho salmon in this study because holding time had no correlation with the probability of recapture. Furthermore, the tag ratio at the Kogrukluk River weir was higher than that of Tatlawiksuk, while actual swimming distance was much farther for fish going to the Kogrukluk River (Table 3). This discrepancy cannot be explained by the delayed mortality hypothesis.

We hypothesize that the fish wheels tended to catch more coho salmon bound to middle basin spawning grounds. While most coho salmon migrate along the bank, not all migrated within 5 m distance from the bank where the fish wheels were placed. In contrast, since driftnets sampled at various parts of the river, the tagged populations by driftnets could be more representative of the coho salmon run. In fact, the tag ratio in driftnets did not differ significantly between middle and upper basin tributaries (Table 10). This difference in various spawning locations indicates a geographical stock separation: coho salmon bound to middle basin spawning grounds are more likely to swim closer to the bank.

Simultaneously, fish wheels were not always efficient in capturing coho salmon. During the first part of the tagging operations the fish wheels were periodically moved as the crews attempted to locate them to better fishing locations. Furthermore, catch efficiency of fish wheels were greatly reduced because of high water during a time when the Bethel Test Fishery Index suggested there should have been an increase in abundance; consequently, it is plausible that the fish wheels missed fish bound for the upper basin, if most of those fish migrate past the tagging sites in the early season. Tag recovery data, however, provided no evidence of a difference in the run timing between middle and upper basin coho salmon stocks.

Thus, we conclude that fish wheels tended to catch more coho salmon bound to middle basin spawning grounds because coho salmon bound to middle basin spawning grounds are more

likely to swim closer to the bank. This distinction indicates that fish wheels may not be an effective method to capture coho salmon for a population estimation. Simultaneously, the catches of drifts were limited in this study. We propose an increase of drift net sampling for future studies to confirm the results of this study.

Regarding the recapture of tagged coho salmon in lower basin downstream from the tagging sites, we know that coho salmon wander before reaching spawning grounds (Jones *et al.* 2001); thus, we were not surprised that many tagged coho salmon were captured in the fisheries or spawning grounds in the lower basin. This wandering behavior, however, violates the Peterson's closed population assumptions (i.e., all tagged and untagged coho salmon eventually go upstream). for which side the abundance estimates were biased is unknown, because not all the lower basin bound tagged fish might be caught and not all tagged fish caught in the lower basin might be bound to lower basin spawning grounds. The range of abundance estimates were made under different scenarios for the number of lower basin bound tagged fish (Table 12). These estimates need to be compared with other estimates.

RECOMMENDATIONS

For the coming years of study, we recommend:

- 1) quickly establish the deployment locations of fish wheels and keep location as stable as possible,
- 2) increase of coho salmon by drift gillnets,
- 3) and improve the tag recovery methods employed at the weirs.

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Table 1. Number of coho salmon tagged and recovered at the Kalskag and Birch Tree Crossing tagging sites on the Kuskokwim River, 2001.

Kalskag Fish Wheel and Drift Gillnet								Birch Tree Crossing Fish Wheel and Drift Gillnet								Total
Date	Coho Salmon Tagged			Coho Salmon Recaptured				Coho Salmon Tagged			Coho Salmon Recaptured					
	Floy Tag Color			Floy Tag Color				Floy Tag Color			Floy Tag Color					
	Pink	White	Total	Green	Pink	White	Total	Green	White	Total	Green	Pink	White			
22-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
23-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
24-Jul	0	0	0	0	0	0	0	2	0	2	0	0	0	0		
25-Jul	2	0	2	0	0	0	0	1	0	1	0	0	0	0		
26-Jul	2	0	2	0	0	0	0	3	0	3	0	0	0	0		
27-Jul	4	0	4	0	0	0	0	2	0	2	0	0	0	0		
28-Jul	2	0	2	0	0	0	0	2	0	2	0	0	0	0		
29-Jul	3	0	3	0	0	0	0	3	0	3	0	0	0	0		
30-Jul	2	0	2	0	0	0	0	13	0	13	0	0	0	0		
31-Jul	3	0	3	0	0	0	0	29	0	29	0	0	0	0		
1-Aug	34	0	34	0	0	0	0	23	0	23	0	0	0	0		
2-Aug	34	0	34	0	0	0	0	21	0	21	0	0	0	0		
3-Aug	53	0	53	0	1	0	1	32	0	32	0	0	0	0		
4-Aug	55	0	55	0	0	0	0	78	0	78	0	0	0	0		
5-Aug	54	0	54	0	0	0	0	87	0	87	0	0	0	0		
6-Aug	49	0	49	0	0	0	0	91	0	91	2	0	0	2		
7-Aug	43	0	43	0	0	0	0	107	0	107	1	3	0	4		
8-Aug	49	0	49	0	0	0	0	72	0	72	1	0	0	1		
9-Aug	35	0	35	0	0	0	0	61	0	61	0	1	0	1		
10-Aug	30	0	30	0	0	0	0	73	0	73	0	0	0	0		
11-Aug	26	2	28	0	0	0	0	77	0	77	0	2	0	2		
12-Aug	32	3	35	1	0	0	1	51	0	51	1	0	0	1		
13-Aug	39	13	52	0	0	0	0	14	0	14	0	0	0	0		
14-Aug	38	10	48	0	0	0	0	36	0	36	0	0	0	0		
15-Aug	34	15	49	0	0	0	0	26	3	29	0	1	0	1		
16-Aug	37	6	43	0	0	0	0	29	6	35	0	0	0	0		
17-Aug	27	12	39	0	2	0	2	13	16	29	0	0	0	0		
18-Aug	20	3	23	0	0	0	0	25	4	29	0	0	0	0		
19-Aug	16	7	23	0	0	0	0	35	14	49	0	0	0	0		
20-Aug	22	4	26	0	0	0	0	18	8	26	2	0	0	2		
21-Aug	7	5	12	0	0	0	0	10	1	11	0	0	0	0		
22-Aug	4	8	12	0	0	0	0	5	0	5	0	0	0	0		
23-Aug	4	1	5	0	0	0	0	4	1	5	0	0	0	0		
24-Aug	3	5	8	0	0	1	1	4	1	5	0	0	0	0		
25-Aug	1	5	6	0	0	0	0	15	3	18	1	0	0	1		
26-Aug	10	4	14	0	0	0	0	30	3	33	0	0	0	0		
27-Aug	14	7	21	0	0	0	0	43	2	45	1	0	0	1		
28-Aug	33	6	39	1	0	0	1	58	0	58	1	1	0	2		
29-Aug	34	4	38	0	1	0	1	37	0	37	1	1	0	2		
30-Aug	27	8	35	0	0	0	0	54	0	54	0	0	0	0		
31-Aug	28	12	40	0	0	1	1	48	0	48	0	0	0	0		
1-Sep	28	11	39	0	2	0	2	70	0	70	1	0	0	1		
2-Sep	35	13	48	0	0	0	0	30	0	30	0	1	0	1		
3-Sep	33	19	52	0	1	0	1	38	0	38	0	0	0	0		
4-Sep	24	0	24	0	0	0	0	23	0	23	0	0	0	0		
5-Sep	24	6	30	1	1	0	2	37	0	37	0	3	0	3		
6-Sep	25		25	0	0	0	0	35		35	0	0	0	0		
7-Sep	14		14	0	0	0	0	27		27	0	0	0	0		
8-Sep	9		9	0	0	0	0	23		23	0	0	0	0		
9-Sep								31		31	0	0	0	0		
10-Sep								28		28	0	0	0	0		
Sub Total	1,102	189	1,291	3	8	2	13	1,674	62	1,736	12	13	0	25		

Table 2. Number of tags deployed at Kalskag and Birch Tree Crossing on the Kuskokwim River, 2001.

<u>Coho Salmon Tagged</u>				
	<u>Tag Color</u>			
Kalskag	Pink	White	Untagged	Total
Right Bank	897	0	29	926
Left Bank	205	0	14	219
Drifting	0	189	32	221
Total	1,102	189	75	1,366
Birch Tree Crossing	Green	White	Untagged	Total
Right Bank	1,334	0	45	1382
Left Bank	340	0	39	380
Drifting	0	62	14	76
Total	1,674	62	98	1,834
Combined	Pink/Green	White	Untagged	Total
Right Bank	2,231	0	74	2,308
Left Bank	545	0	53	599
Drifting	0	251	46	297
Total	2,776	251	173	3,200

Table 3. Number tags by color recovered at weir sites located downstream and upstream from Kalskag and Birch Tree Crossing tagging sites on the Kuskokwim River, 2001.

River Location	Distance from Tag Sites (km)	Weir Location	Tags Recovered and Observed	Total Counted	Tag Ratio						
	Confluence	Weir	Tag Color								
			Pink ^{1/}	Green ^{2/}	White ^{3/}	Total					Wheels
Lower	-150	-198	Kwethluk River ^{4/}	5	2	0	7	19,196	0.0004	--	0.0004
Lower	-91	-139	Tuluksak River ^{4/}	5	4	3	12	12,273	0.0007	0.0002	0.0010
Middle	188	193	George River ^{5/, 6/}	19	37	5	61	8,400	0.0067	0.0006	0.0073
Middle	230	450	Kogrukluk River ^{5/, 6/}	58	64	8	130	16,200	0.0075	0.0005	0.0080
Upper	307	310	Tatlawiksuk River ^{5/, 6/}	6	8	3	17	5,667	0.0025	0.0005	0.0030
Upper	506	591	Takotna River ^{5/, 6}	3	2	1	6	2,351	0.0021	0.0004	0.0026
Total				96	117	20	233	64,087			

^{1/} Tagged from fish wheels near Kalskag

^{2/} Tagged from fish wheels at Birch Tree Crossing

^{3/} Tagged from drift gillnets near Kalskag or Birch Tree Crossing

^{4/} U.S. Fish and Wildlife Service.

^{5/} Kuskokwim Native Association

^{6/} Alaska Department of Fish and Game.

Table 4. Number of recovered tags from coho salmon by subsistence, commercial and sport fishers at locations downstream and upstream from the Kalskag and Birch Tree Crossing tagging sites on the Kuskokwim River, 2001.

Community	Fishery Type															
	Subsistence				Commercial				Sports				Total			
	Tag Color				Tag Color				Tag Color				Tag Color			
	Pin	Gree	Whit	Tota	Pin	Gree	Whit	Tota	Pin	Gree	Whit	Tota	Pin	Gree	Whit	Tota
Downstream																
Napakiak Village	0	0	0	0	2	5	0	7	0	0	0	0	2	5	0	7
Bethel	1	1	0	2	3	6	0	9	0	0	0	0	4	7	0	11
Kwethluk	2	5	0	7	6	1	1	8	0	0	0	0	8	6	1	15
Achiachak	1	3	0	4	4	7	0	11	0	0	0	0	5	10	0	15
Akiak	0	1	0	1	4	9	0	13	0	0	0	0	4	10	0	14
Tuluksak	7	3	0	10	4	4	0	8	0	0	0	0	11	7	0	18
Lower Kalskag	3	5	1	9	0	0	0	0	0	0	0	0	3	5	1	9
Total	14	18	1	33	23	32	1	56	0	0	0	0	37	50	2	89
Upper Kalskag ^{1/}	11	7	0	18	0	0	0	0	0	0	0	0	11	7	0	18
Upstream																
Aniak	7	8	0	15	0	0	0	0	1	5	0	6	8	13	0	21
Chuathbaluk	1	2	1	4	0	0	0	0	0	0	0	0	1	2	1	4
George Town	0	0	0	0	0	0	0	0	1	2	0	3	1	2	0	3
Napaimiut	1	2	0	3	0	0	0	0	0	0	0	0	1	2	0	3
Red Devil	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
Sleetmute	3	3	0	6	0	0	0	0	1	2	1	4	4	5	1	10
Stony River	7	4	0	11	0	0	0	0	0	0	0	0	7	4	0	11
McGrath	1	1	0	2	0	0	0	0	0	0	0	0	1	1	0	2
Medra	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
Nikolai	0	0	2	2	0	0	0	0	0	0	0	0	0	0	2	2
Total	20	22	3	45	0	0	0	0	3	9	1	13	23	31	4	58
Unknown ^{2/}	1	0	0	1	2	1	0	3	0	0	0	0	3	1	0	4
Total	46	47	4	97	25	33	1	59	3	9	1	13	74	89	6	169

^{1/} Recovery location is near tagging sites.

^{2/} Incomplete tag recovery information.

Table 5. Coho salmon swim speed (km/day) based on recoveries at escapement weir sites and volunteer tag returns on the Kuskokwim River, 2001.

Tag Recoveries	Tag Dates	N	Average	Median	Range
Weir Locations					
Tuluksuk River	8/10 - 8/12	2	8.5	0	8 - 9
George River	7/30 - 8/6	7	9.4	9	7 - 12
George River	8/18 - 9/9	32	15.4	14	9 - 42
Kogrukluk River	7/25 - 8/17	76	18.9	19	10 - 19
Kogrukluk River	8/18 - 9/6	53	27.5	28	14 - 38
Tatlawiksuk River	8/23 - 9/3	3	25.8	28	18-31
Takotna River	8/8	1	33.1		
Volunteer Recoveries					
Below Tag Sites	7/24 - 8/15	81	21.5	18	1 - 91
Below Tag Sites	8/20 - 9/3	8	33.3	34	5 - 91
Above Tag Sites	8/1 - 8/16	37	7.7	7	0 - 23
Above Tag Sites	8/17 - 9/6	28	23.2	19	0 - 148

Table 6. Length distribution of coho salmon at weir locations.

River Location	Distance from Tag Sites (km)	Weir Location	Range (mm)	n	Mean (mm)
			345 – 675	2,979	578.5
Lower Basin	-150	Kwethluk River	490 – 670	208	593.2
Lower Basin	-91	Tuluksak River	440 – 580	208	540.9
Middle Basin	188	George River	495 – 670	495	562.3
Middle Basin	230	Kogrukluk River	470 – 670	580	576.7
Upper Basin	307	Tatlawiksuk River	410 – 670	608	571.7
Upper Basin	506	Takotna River	520 – 650	294	566.7
Recaptured			510 – 650	152	585.4

Table 7. Logistic Regression Table.

Parameter	Estimate	SE	t-ratio	p-value	Odds Ratio
Constant	-5.200	1.170	-4.443	0.000	
Length	0.004	0.002	2.111	0.035	1.004
Holding Time	-0.012	0.033	-0.344	0.731	0.989

Chi-square = 4.704, df = 2, P = 0.095

Table 8. Population estimate for coho salmon upstream from Kalskag (rkm 172) on the Kuskokwim River, 2001.

Initial marked population	Pink	1102
	White	189
Recovered in Lower Basin	Pink	-47
	White	-5
Effective marked population	M =	1239

Recovery Site	Number Examined	Number Unmarked	Number Marked	Chapman Estimator	CV	Tag Ratio
Birch Tree Crossing	1,834	1,821	13	162,528	0.256	0.0071

Table 9. Population estimate for coho salmon upstream from Kalskag and Birch Tree Crossing tagging sites based on tags recoveries at the George, Tatlawiksuk, Kogrukluk, and Takotna River weir site on the Kuskokwim River, 2001.

Initial marked population:	Pink	1102				
	Green	1674				
	White	251				
Recovered in Lower Basin	Pink	-47				
	Green	-56				
	White	-5				
Effective marked population:		2919				
Middle Basin	Number Examined	Number Unmarked	Number Marked	Chapman Estimator	CV	Tag Ratio
George River	8,400	8,339	61	395,659	0.124	0.0073
Kogrukluk River	16,200	16,070	130	361,121	0.085	0.0080
Middle Basin Total	24,600	24,409	191	374,139	0.069	0.0078
Upper Basin						
Tatlawiksuk River	5,667	5,650	17	919,475	0.228	0.0030
Takotna River	2,351	2,345	6	981,119	0.353	0.0026
Upper Basin Total	8,018	7,995	23	975,644	0.199	0.0029

Table 10. Population estimate for coho salmon upstream from Kalskag and Birch Tree Crossing tagging sites based on drift tags recoveries at the George, Tatlawiksuk, Kogrukluuk, and Takotna River weir sites on the Kuskokwim River, 2001.

Initial marked population:	White	251				
Recovered Lower Basin	White	-5				
Effective marked population:		246				
Middle Basin	Number Examined	Number Unmarked	Number Marked	Chapman Estimator	CV	Tag Ratio
George River	8,400	8,395	5	345,840	0.373	0.0006
Kogrukluuk River	16,200	16,192	8	444,626	0.310	0.0005
Middle Basin Total	24,600	24,587	13	434,031	0.251	0.0005
Upper Basin						
Tatlawiksuk River	5,667	5,664	3	349,998	0.443	0.0005
Takotna River	2,351	2,350	1	290,471	0.575	0.0004
Upper Basin Total	8,018	8,014	4	396,138	0.404	0.0005
Overall	32,618	32,601	17	447,604	0.221	0.0005

Table 11. Population estimate for coho salmon upstream from Kalskag and Birch Tree Crossing tagging sites based on tags recoveries at the George, Tatlawiksuk, Kogrukluk, and Takotna River weir sites on the Kuskokwim River, 2001.

Initial marked population:	Pink	1102				
	Green	1674				
Recovered in Lower Basin	Pink	-47				
	Green	-56				
Effective marked population:		2673				
Middle Basin	Number Examined	Number Unmarked	Number Marked	Chapman Estimator	CV	Tag Ratio
George River	8,400	8,344	56	394,109	0.129	0.0067
Kogrukluk River	16,200	16,078	122	352,206	0.087	0.0075
Middle Basin Total	24,600	24,422	178	367,502	0.072	0.0072
Upper Basin						
Tatlawiksuk River	5,667	5,653	14	1,010,414	0.249	0.0025
Takotna River	2,351	2,346	5	1,048,207	0.377	0.0021
Upper Basin Total	8,018	7,999	19	1,072,139	0.217	0.0024

Table 12. Range of population estimate for coho salmon on the Kuskokwim River under different downstream-tagged fish scenario, 2001.

	Number of tagged fish in downstream						
	× 0.5	× 1	× 2	× 5	× 10	× 15	× 20
Middle Basin							
Fish wheel only	374,580	367,502	353,346	310,879	240,099	169,320	98,540
Drifts only	438,424	434,031	425,245	398,887	354,956	311,026	267,096
Fish wheels & Drifts	381,058	374,139	360,301	318,787	249,597	180,406	111,216
Upper Basin							
Fish wheel only	1,092,788	10,72,139	1030,841	906,879	700,459	493,969	287,480
Drifts only	400,147	396,138	388,119	364,062	323,967	283,872	243,777
Fish wheels & Drifts	993,687	975,644	939,559	831,302	650,875	470,447	290,020

× # indicates that the actual number of downstream tagged fish is # times of that reported.

× 1 indicates the original estimate.

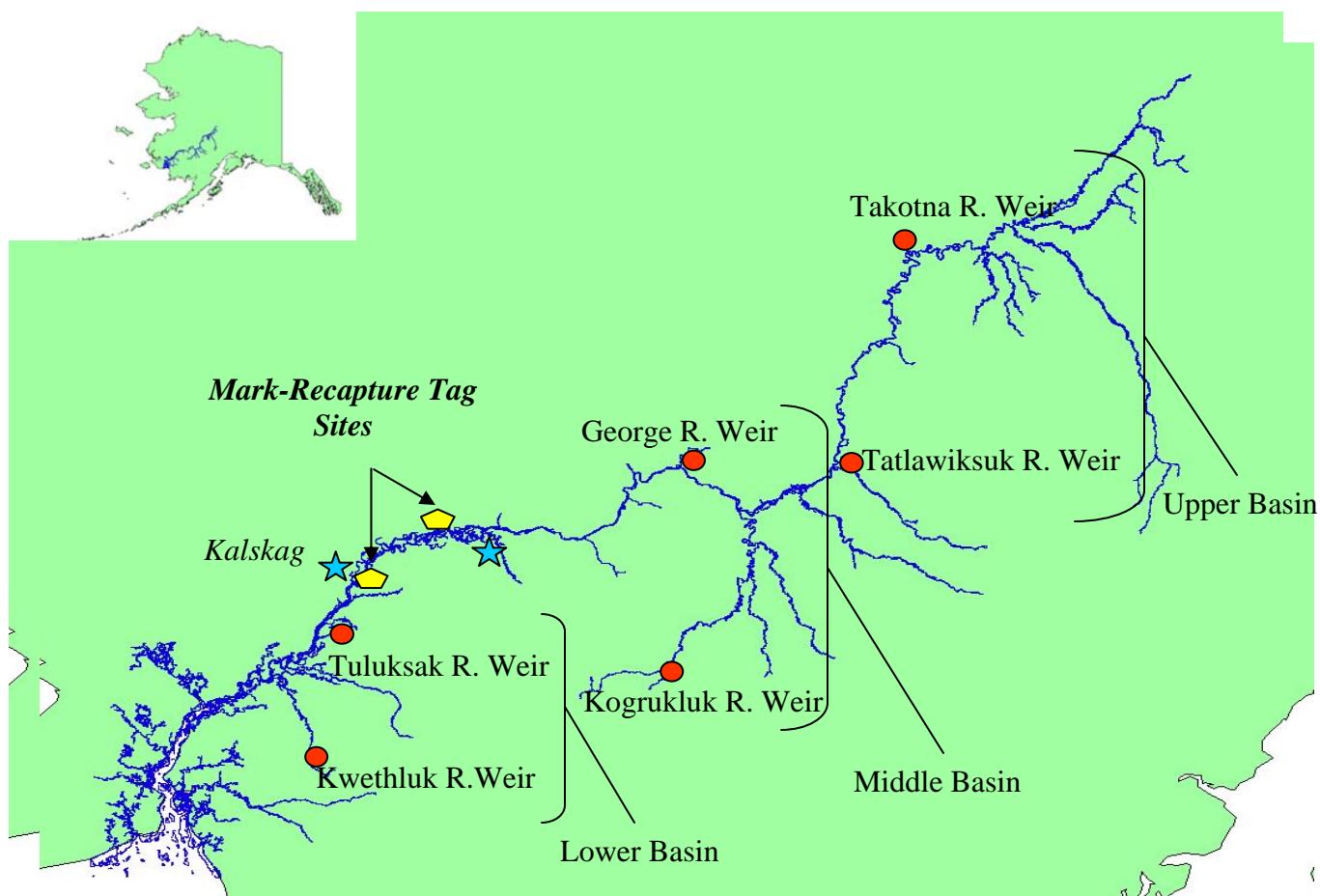


Figure 1. Locations of tagging and weir sites on the Kuskokwim River, 2001.

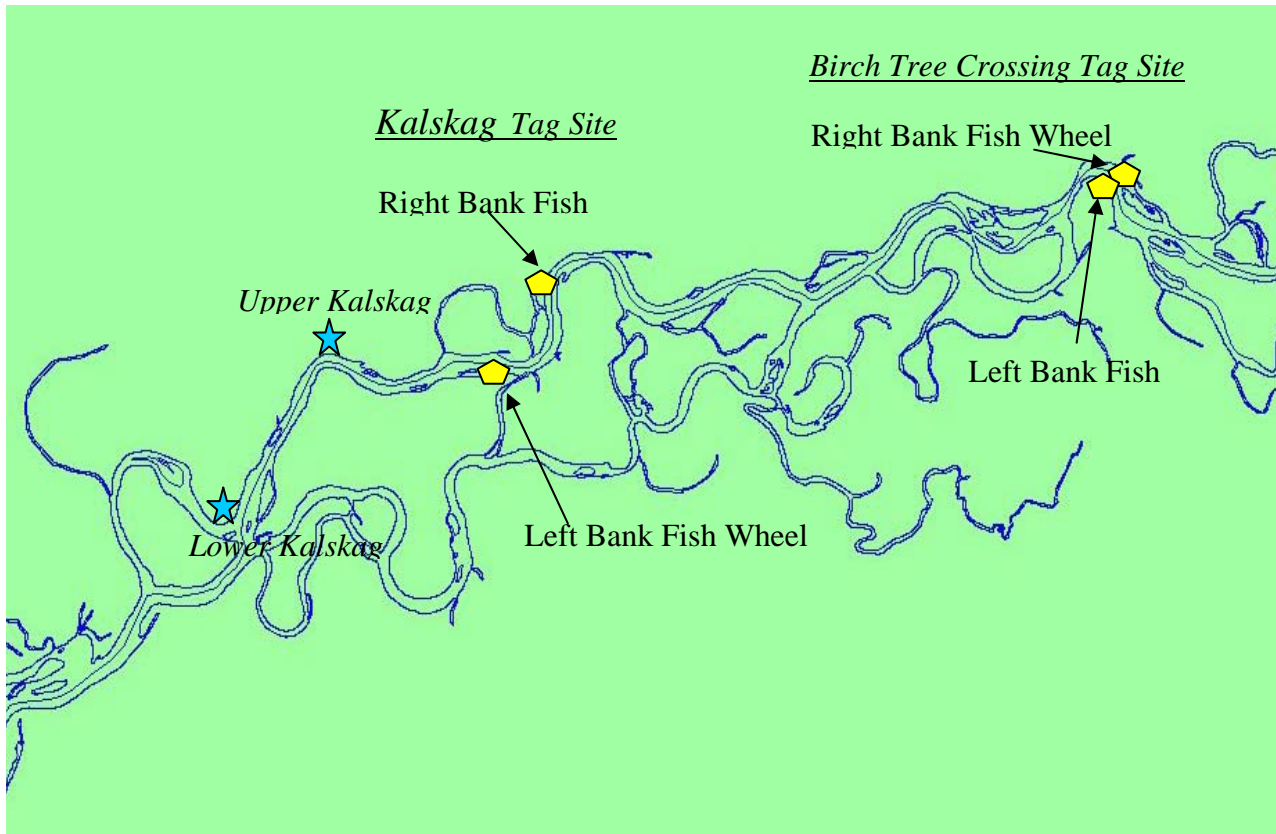


Figure 2. Location of fish wheels at tagging sites on the Kuskokwim River, 2001.

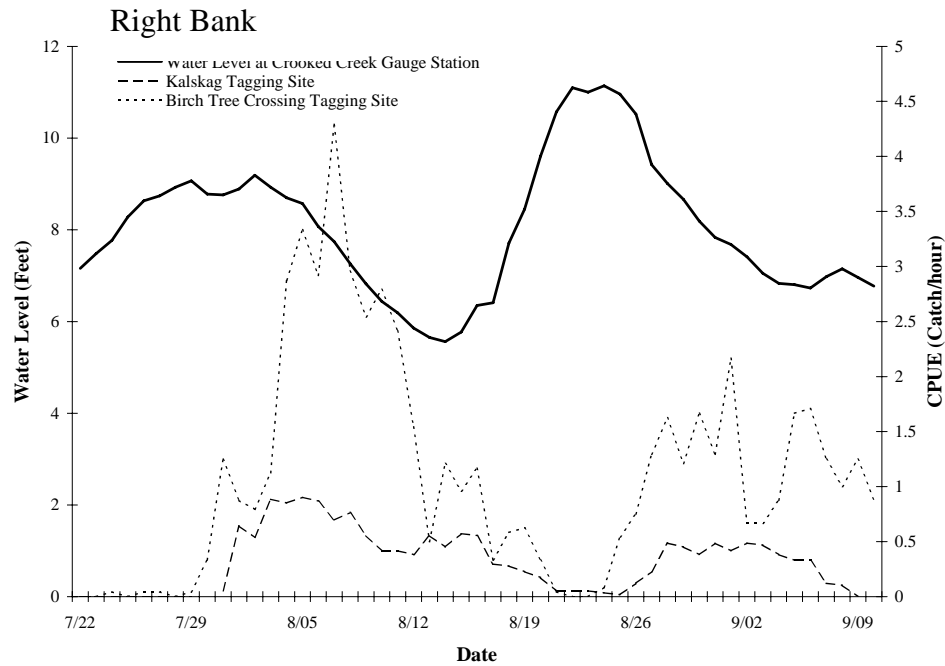


Figure 3. Catch per unit effort (CPUE) of the right bank fish wheels at Kalskag and Birch Tree Crossing tagging sites on the Kuskokwim River, 2001.

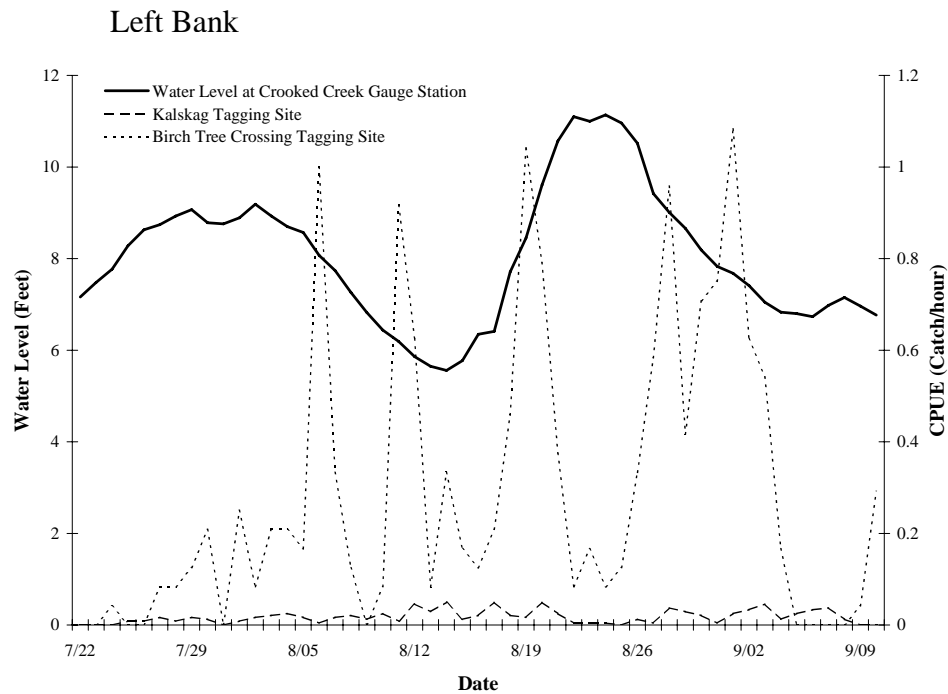


Figure 4. Catch per unit effort (CPUE) of the left bank fish wheels at Kalskag and Birch Tree Crossing tagging sites on the Kuskokwim River, 2001.

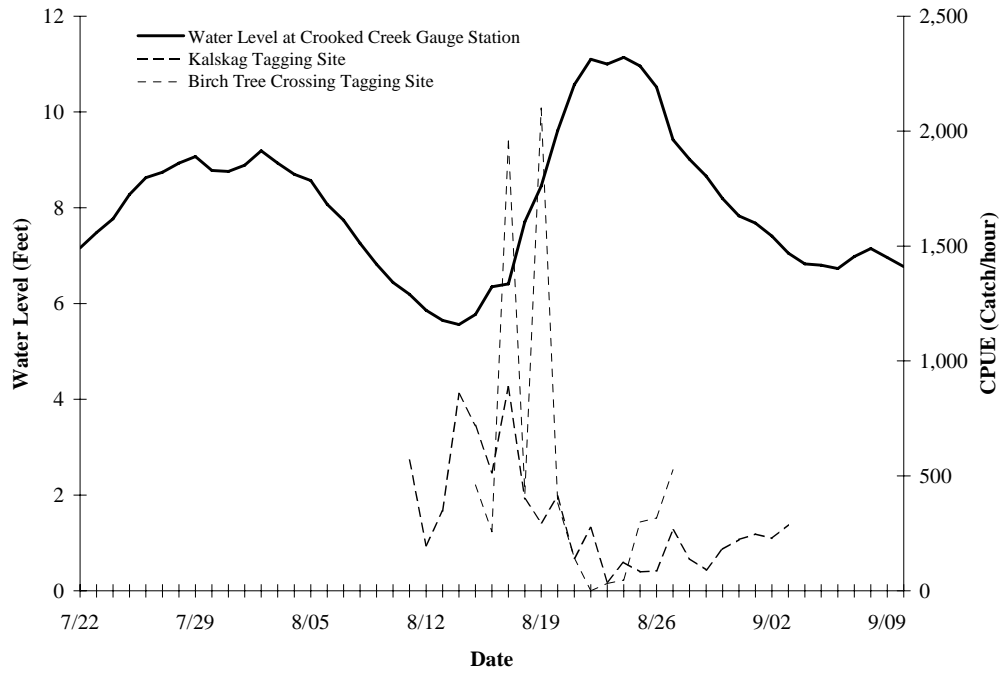


Figure 5. CPUE of drift gillnets at the Kalskag and Birch Tree Crossing Tagging sites on the Kuskokwim River, 2001.

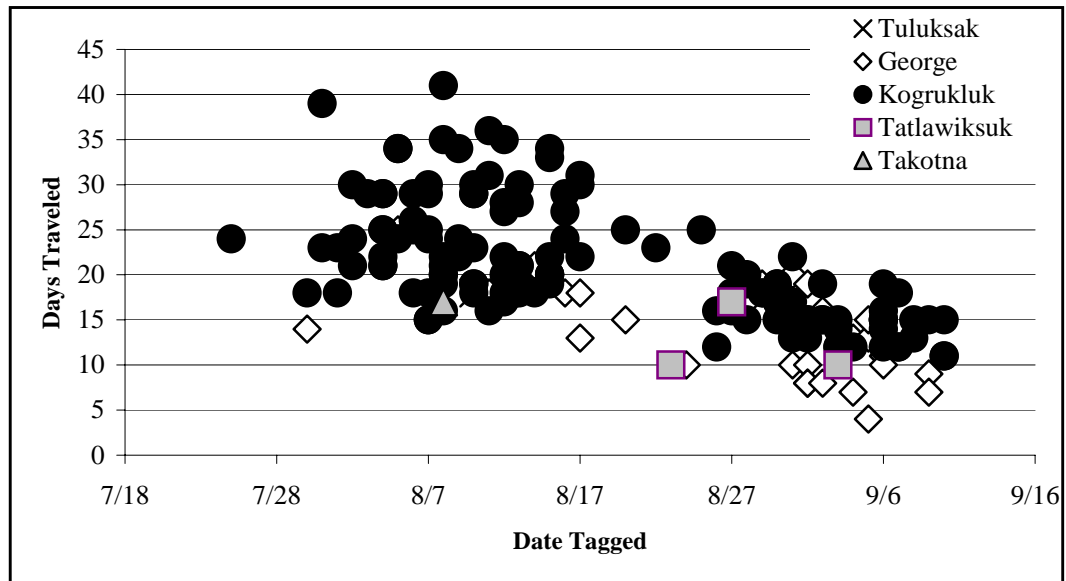


Figure 6. Number of day's coho salmon traveled from the Kalskag and Birch Tree Crossing tagging sites to the Tuluksak, George, Kogrukluk, Tatlawiksuk, and Takotna river weir on the Kuskokwim River, 2001.

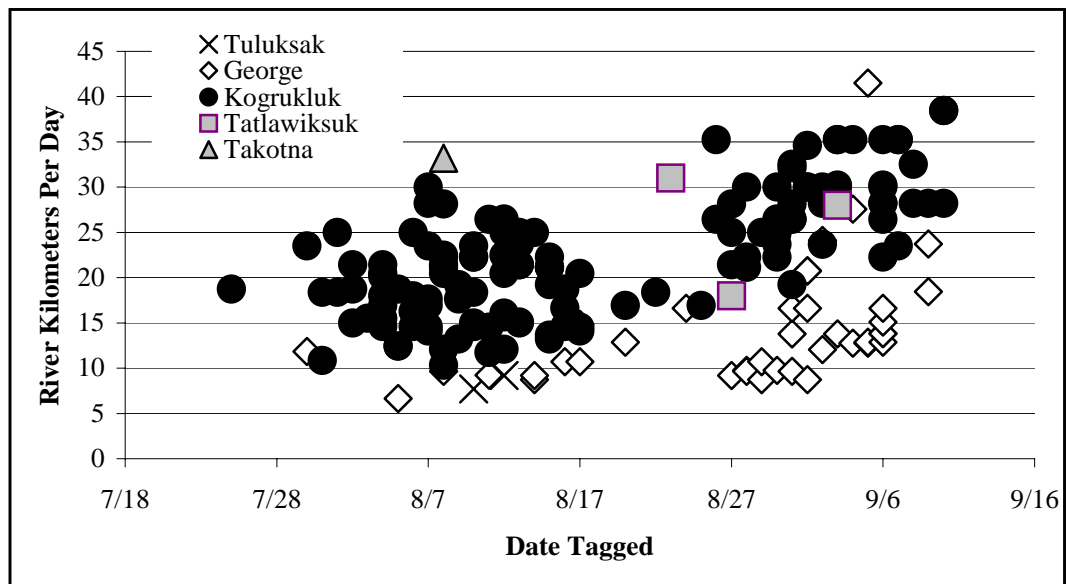


Figure 7. Travel speed (km/day) of coho salmon traveled from the Kalskag and Birch Tree Crossing tagging sites to the Tuluksak, George, Kogrukluk, Tatlawiksuk, and Takotna river weir on the Kuskokwim River, 2001.

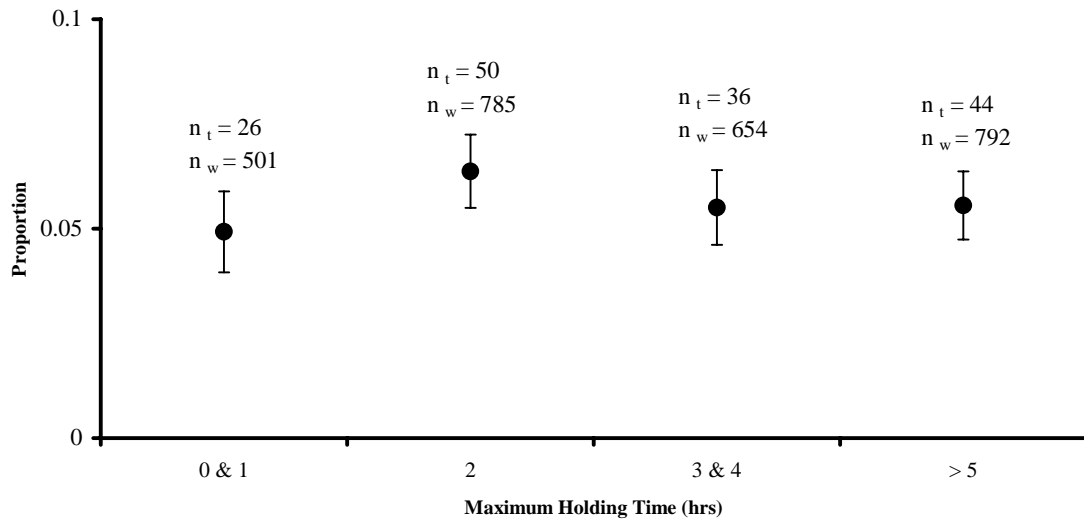


Figure 8. The maximum time Kuskokwim River coho salmon were held in live boxes (n_t) before being tagged and the proportion of the held coho salmon to the untagged coho salmon (n_w) counted past weir sites. Maximum live box holding times are binned into four